Flood Hazard Maps Generation caused by hypothetical failure of the Tabqa Dam by use of HEC-RAS 2D model

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Introduction

- Extreme natural phenomena have been considered among the most dangerous disasters for humans since ancient times.
- Earthquakes, volcanoes, lightning strikes, hurricanes, droughts, and floods are a danger threatening human societies and require taking all necessary measures to ward them off.

- Floods are considered highly destructive natural disasters because they occur relatively quickly and over a large area.
- The reason for increasing the scale of human and material losses from floods is that most major cities, residential complexes, and various projects are built on the banks of rivers and waterways.

- In the past few years, the risk of flooding has gone up a lot.
- This is because of climate change and the building of more large dams that hold a lot of water.
- The cause of floods is no longer limited to natural phenomena such as earthquakes or heavy rains.
- Maintenance errors, inaccurate designs, acts of sabotage, and military operations may become one of the reasons for the collapse of dams and the occurrence of floods.

- The Tabqa Dam area has recently been exposed to natural disasters such as earthquakes and military and sabotage operations.
- Therefore, flood risk maps must be prepared to create an early warning system to assist decision-makers when a flood emergency occurs.

Objectives

- This study aims to use a two-dimensional hydrodynamic model (HEC RAS 2D) to track the flood wave resulting from a hypothetical collapse of the Syrian Tabqa Dam to:

1. Determine the arrival time, elevation, and width of the inundation area along the Euphrates River from the Tabqa Dam in Syria to the Haditha Dam in western Iraq.
2. Measuring the ability of Haditha Dam to store and pass this flood wave.

Study Area

- The study area is located along the Euphrates River between the Tabqa Dam in Syria and the Haditha Dam in Iraq.
- The distance between the two dams along the Euphrates River is about 575 km, including 370 km in Syria and 205 km inside Iraqi territory.

Study Area

- Tabqa Dam, sometimes called the Euphrates Dam, is located in Raqqa Governorate on the Euphrates River in Syria. The earthen-type dam began operations in 1973.
- The length of the dam is 4500 meters, the height is 60 meters, the summit level is 307 meters, the base width is 512 meters at ground level, and the top width is 19 meters.
- Al-Asad Lake is the lake that formed upstream of the dam.
- It has a length of 80 km, an average width of 8 km, and a surface area of 525 km2.
- The maximum storage capacity of the lake is 11.7 billion cubic meters.

Study Area

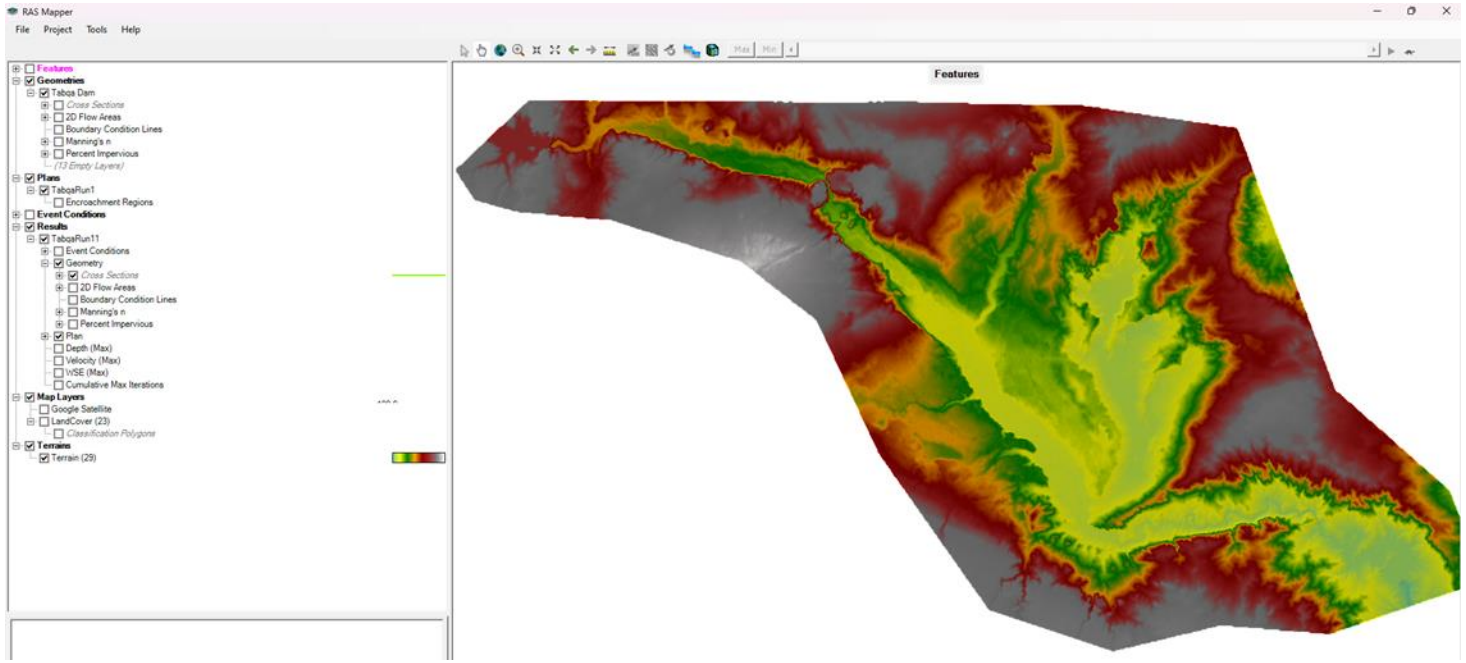
- Haditha Dam, also known as Al-Qadisiyah Dam, is located in Anbar Governorate, western Iraq. The earthen dam began operations in 1985.
- It has a length of 8933 meters, a height of 57 meters, a peak level of 154 meters, and a width of 20 meters at the top of the dam.
- Haditha Lake, with a surface area of about 500 km2, has a maximum storage capacity of 8.28 billion cubic meters.
- We use these two dams to generate electricity, prevent floods, and store water for use in times of scarcity.

Methodology/ Hydrodynamic model generation

- The process of routing the flood wave and determining its characteristics along the river's course is complex.
- The unsteady flow of water during floods, the numerous variations in the roughness coefficient of the river and flood plains, and the frequent occurrence of meanders in the paths of natural rivers all contribute to this.
- The HEC RAS 2D model uses the Navier-Stokes equations that describe the movement of fluids in two dimensions.
- After simplifying the equations and assuming a uniform density of water, incompressible flow, and hydrostatic pressure, we model flood movement in rivers by combining mass and momentum conservation equations.

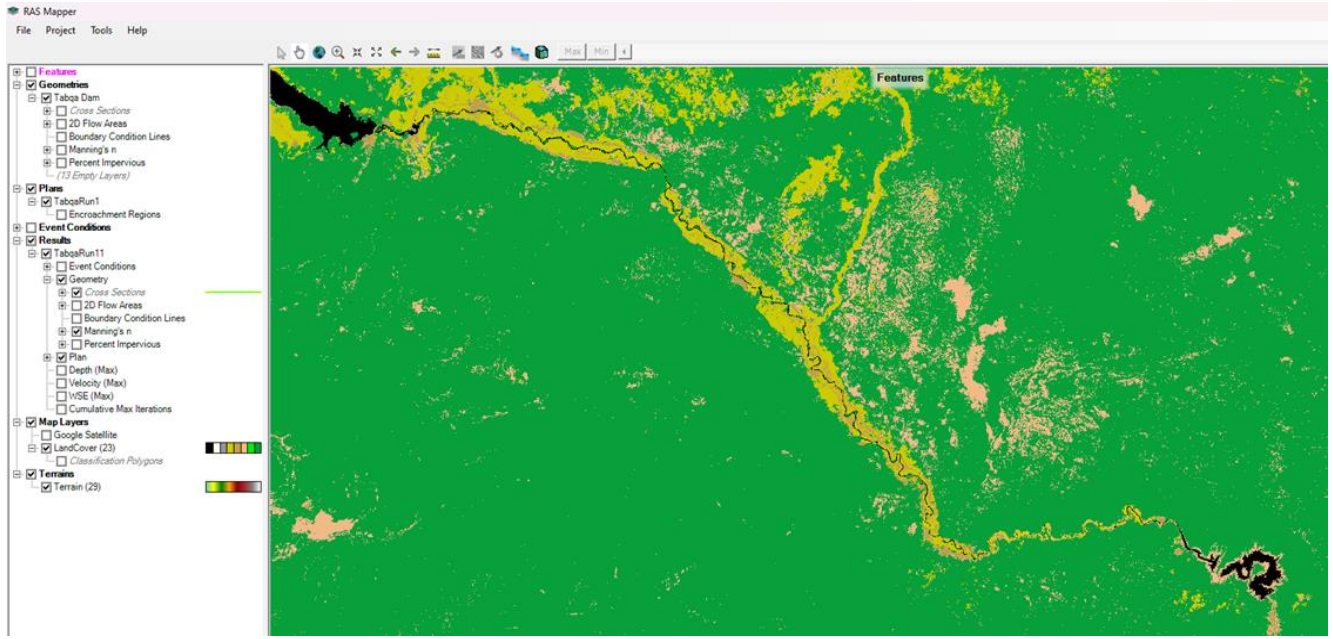
Hydrodynamic model generation

- Prepare all hydraulic, geometric, topographic, and land use data for the dam and study area, to simulate the dam's collapse and track the ensuing flood wave.
- Digital elevation models (DEM) of the study area with a resolution of 12.5 meters were prepared .
- The RAS Mapper tool is entered DEM into the HEC RAS 6.5 model, representing the boundaries of the study area between the Haditha and Tabqa dams.



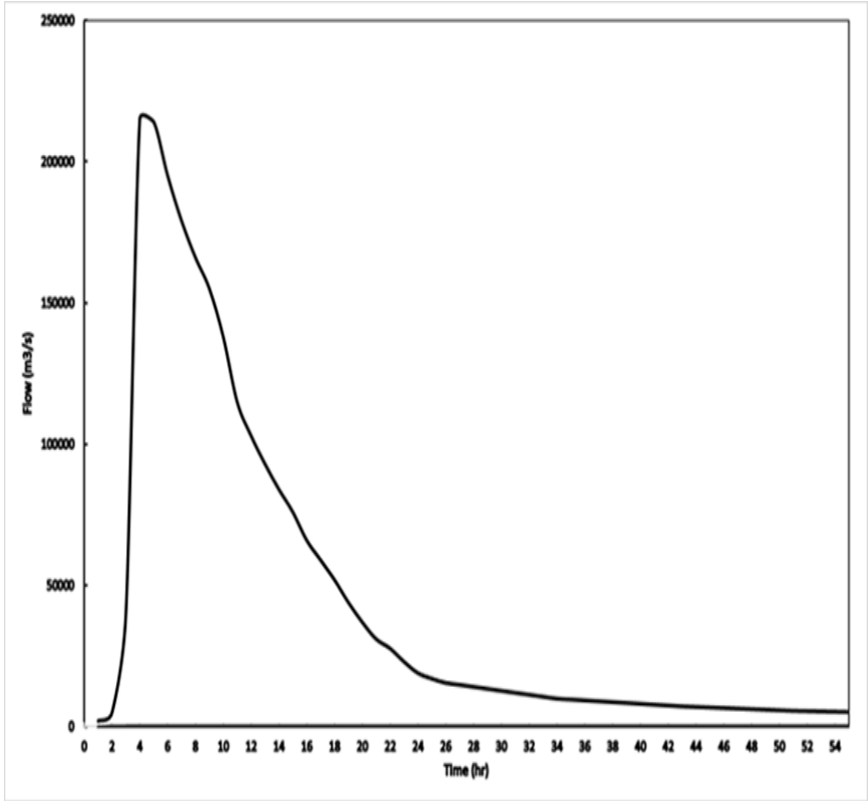
Hydrodynamic model generation

- The land use land cover satellite image with a resolution of 30 meters was prepared and included in the model through the Ras Mapper tool.
- It is used to determine some hydraulic characteristics of the area, such as the values of the Manning roughness coefficient for the study area .
- The Manning coefficient values were set for the main river channel area at a value of 0.028.
- The Manning coefficient values for flood plains were distributed between 0.05 and 0.1 depending on the type of land use, such as barren lands, agricultural lands, or residential areas.



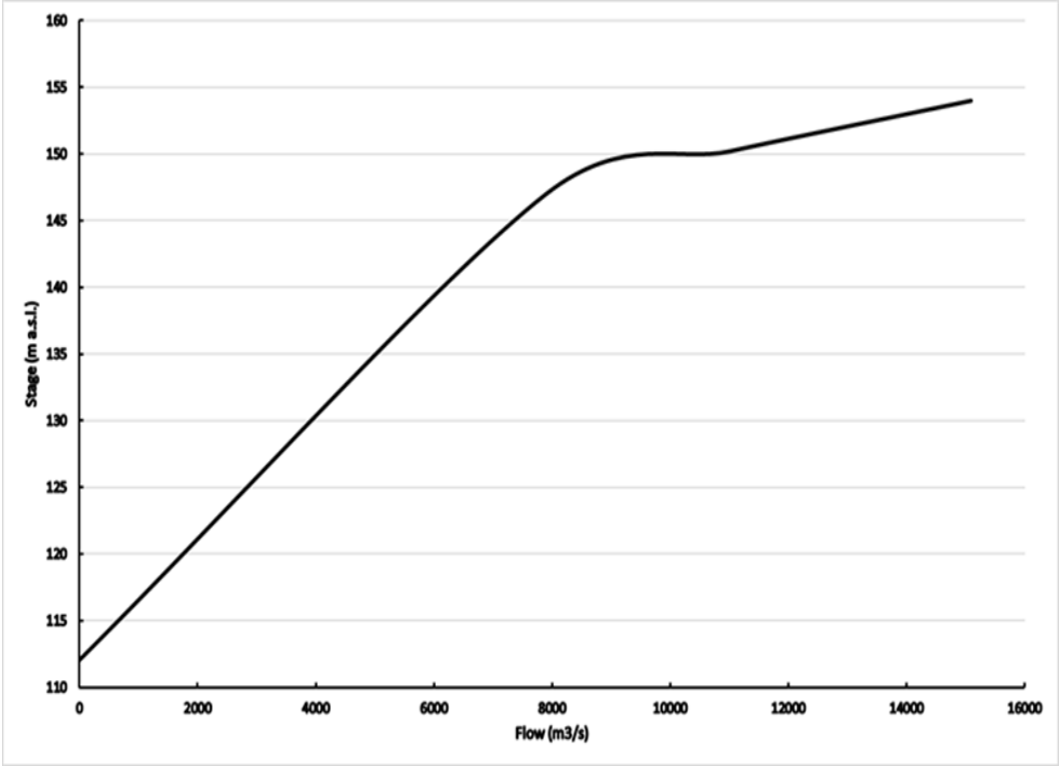
Hydrodynamic model generation

- To determine the flood hydrograph caused by the collapse of a dam, the dam data must be known, such as the height, length, type of dam, and size and length of the reservoir in front of the dam.
- It relies on equations developed based on the analysis of a case study of actual dam failure for various reasons.
- The flood hydrograph of the Tabqa dam was calculated based on the collapse aperture coefficients extracted from the equations of Froehlich (1995), where the collapse hydrograph was used as a boundary condition for the upstream of the study area.



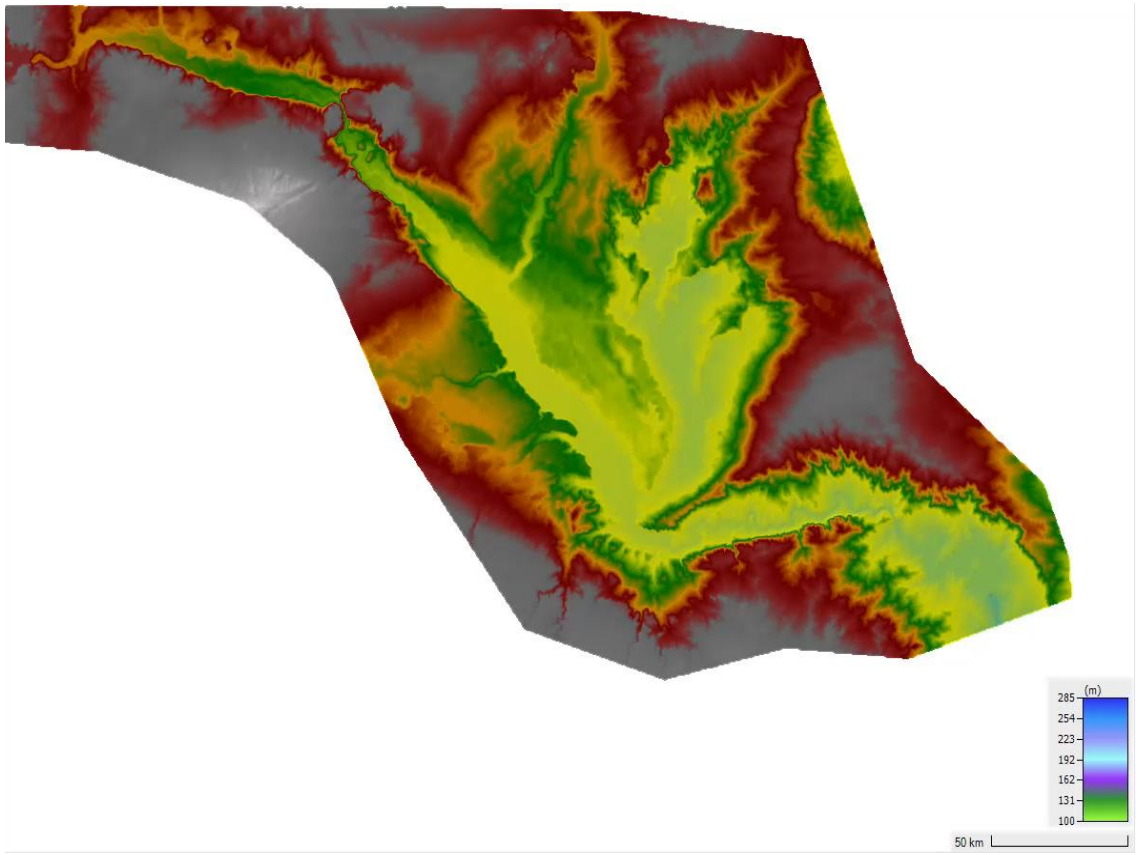
Hydrodynamic model generation

- A stage-flow hydrograph was used as a downstream boundary condition at Haditha Dam.
- It is determined based on the maximum design discharge that can be released from the dam's gates and spillway at different water levels upstream of the dam.



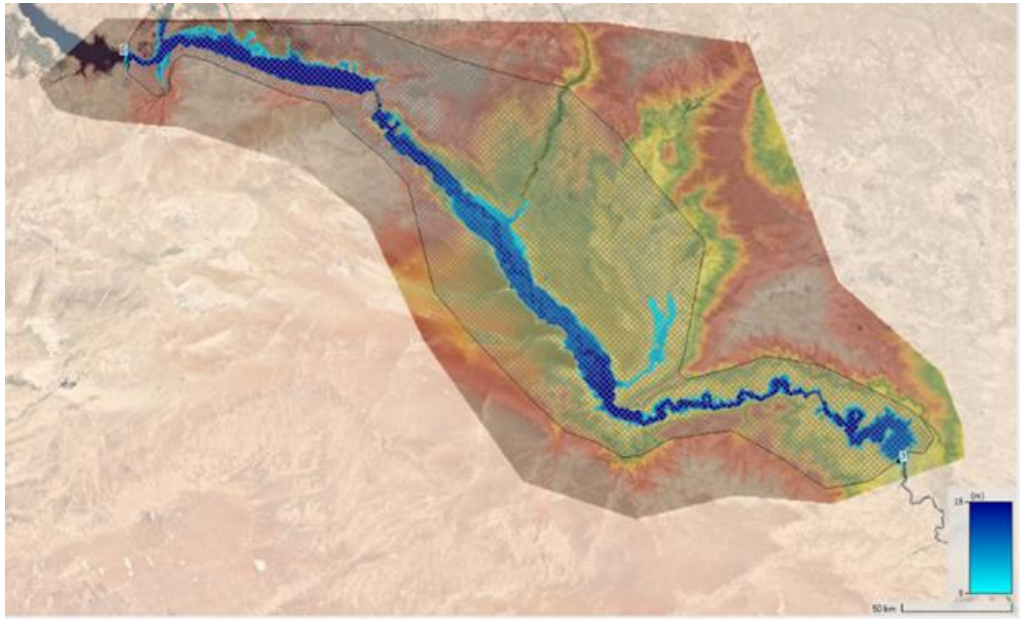
Results

- The HEC RAS model was run for unsteady flow with U/S & D/S boundary conditions.
- Using the land's topography obtained from DEM via Ras Mapper and after extracting hydraulic parameters such as the Manning roughness coefficient from the land use land cover satellite images.
- Flood wave tracking data were obtained along the study area.

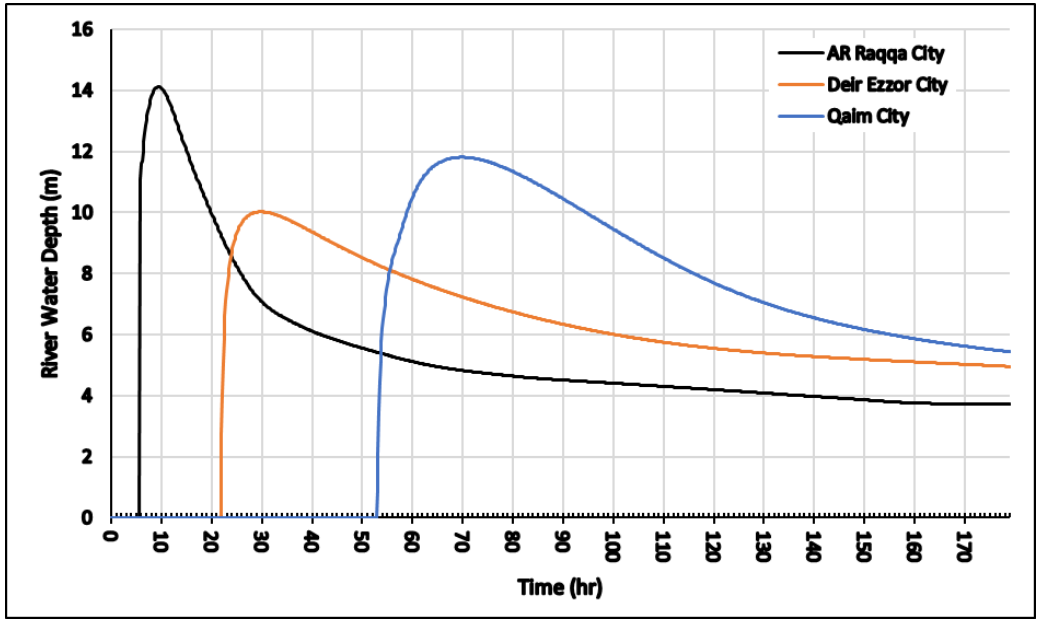


Results and Discussions

- Along the 575 km study area, maps were made to show the highest flood depth, maximum flow speed, and the widest area that would be flooded.
- The flood wave begins at a height of 28.4 meters and gradually gets shallower as it moves downstream of the study area. This is because as it moves downstream, its energy is lost and its speed slows down.



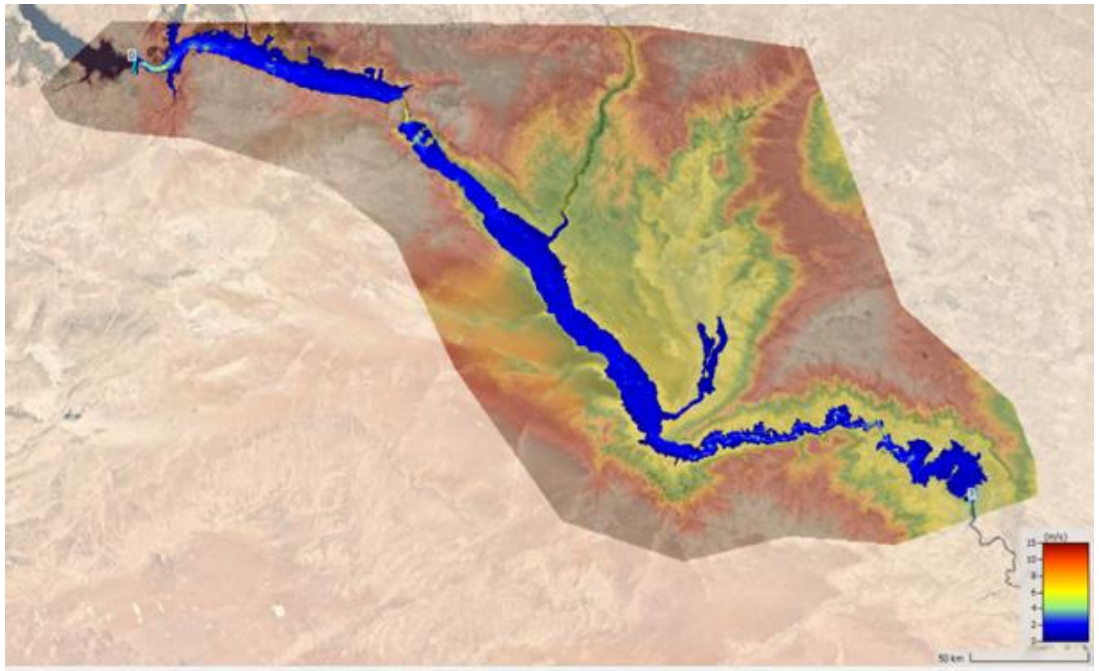
The maximum flood depth along the study area



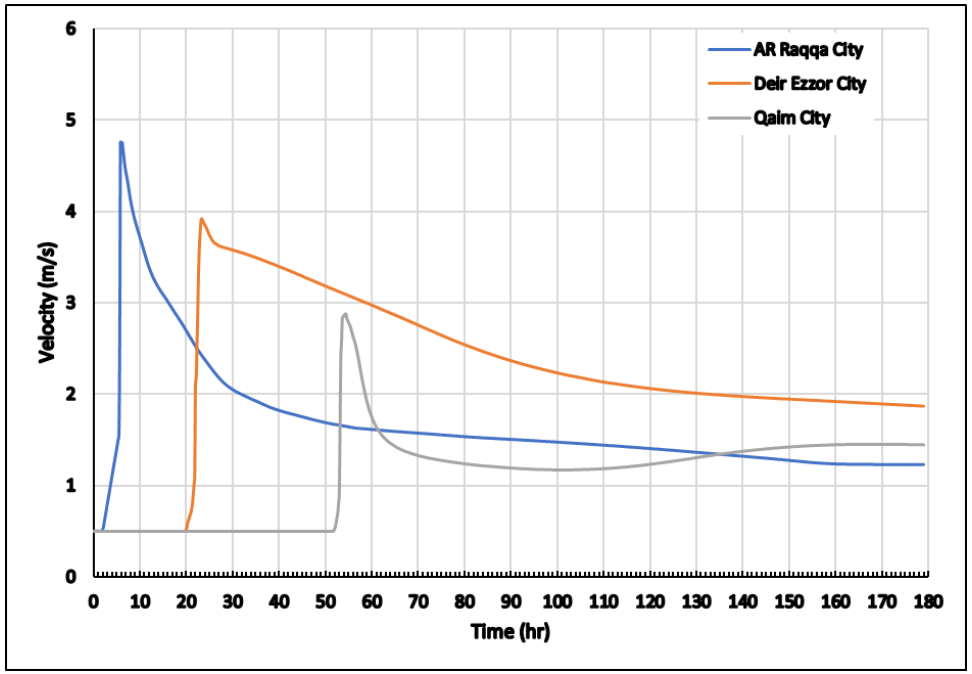
The Euphrates River water depth at AR Raqqa, Deir Ezzor, and Qaim cities

Results

- The flow speed starts at 10.7 m/s at the Tabqa dam and steadily lowers, sometimes increasing at river bottlenecks and when the shoulders are high enough to block the flood wave's transverse spread.



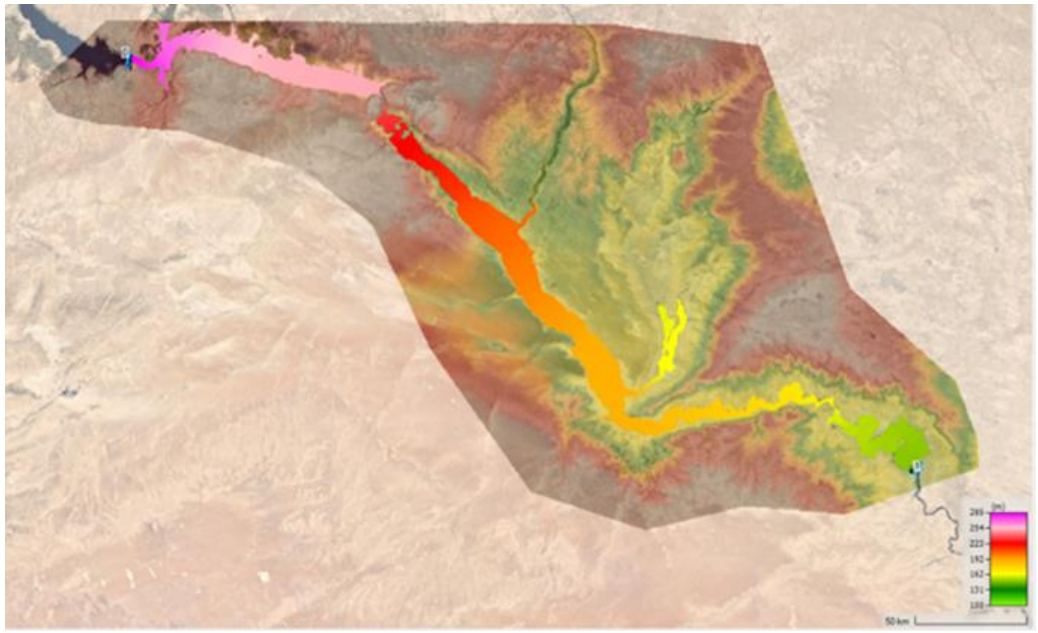
The maximum flow velocity along the study area



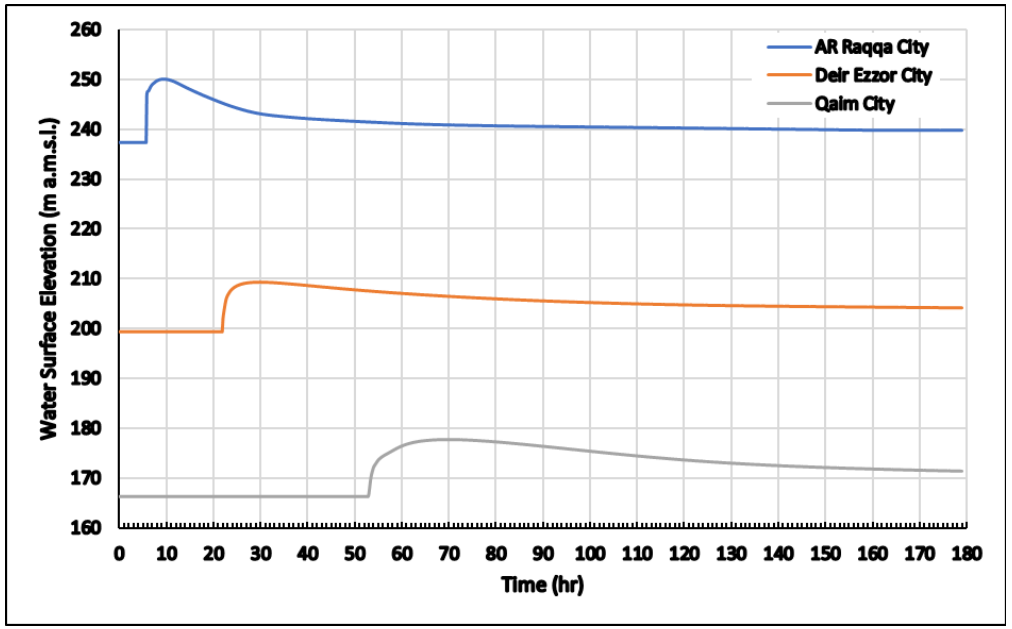
The Euphrates River flow velocity at AR Raqqa, Deir Ezzor, and Qaim cities

Results

- Due to the presence of high terrain on the river's shoulders, some areas have limited inundation width, while others, like the mouths of valleys, experience long-distance flooding, particularly in the Baghouz area, which is naturally lowland.



The maximum water surface elevation along the study area



The Euphrates River water surface elevation at AR Raqqa, Deir Ezzor, and Qaim cities

Results

- Data on the arrival time, elevation, depth, and width of the maximum inundation area of the flood wave were extracted for all important areas along the study area.

City	Distance from Tabqa Dam (km)	Time of flood wave arrive after dam breach beginning (hr)	Max water surface elevation (m a.s.l.)	Max depth (m)	Max velocity (m/s)	Max width of inundation (km)
Downstream Tabqa dam	1	4.20	284.5	28.4	10.7	3.71
AR Raqqa	43	7:15	253.2	17.1	3.3	15.8
Deir Ezzor	199	21:45	208.7	8.9	2.3	11.1
Mayadeen	260	32:45	195.1	10.1	2.1	11.4
Sayyal	347	47:00	179.7	10.7	1.2	13.5
Qaim	375	54:20	178.2	11.9	1.7	4.9
Rawa	510	70:00	156.2	18.2	1.9	1.1
Upstream Haditha Dam	574	90:45	154 then Haditha dam will collapse at time 151:30	54	0.42	9.5

Conclusion and Recommendations

- There are hazards of sinking cities, villages, and vital facilities on both banks of the Euphrates River in Syria and Iraq along the research area.
- Maps of the submerged areas, the timing of the arrival of the flood wave, and its depth were prepared to take precautionary measures in construction work, emergency evacuation work, and civil defense roads, and to create early warning methods according to the category of expected danger.
- The results showed that the Haditha Dam reservoir absorbed a large portion of the flood wave as the dam worked at full capacity to drain the next flood wave, but due to the magnitude of the flood wave discharge, the lake level exceeded the top of the dam. Which led to the collapse of the dam 151.5 hours after the collapse of the Tabqa Dam.

Thank you